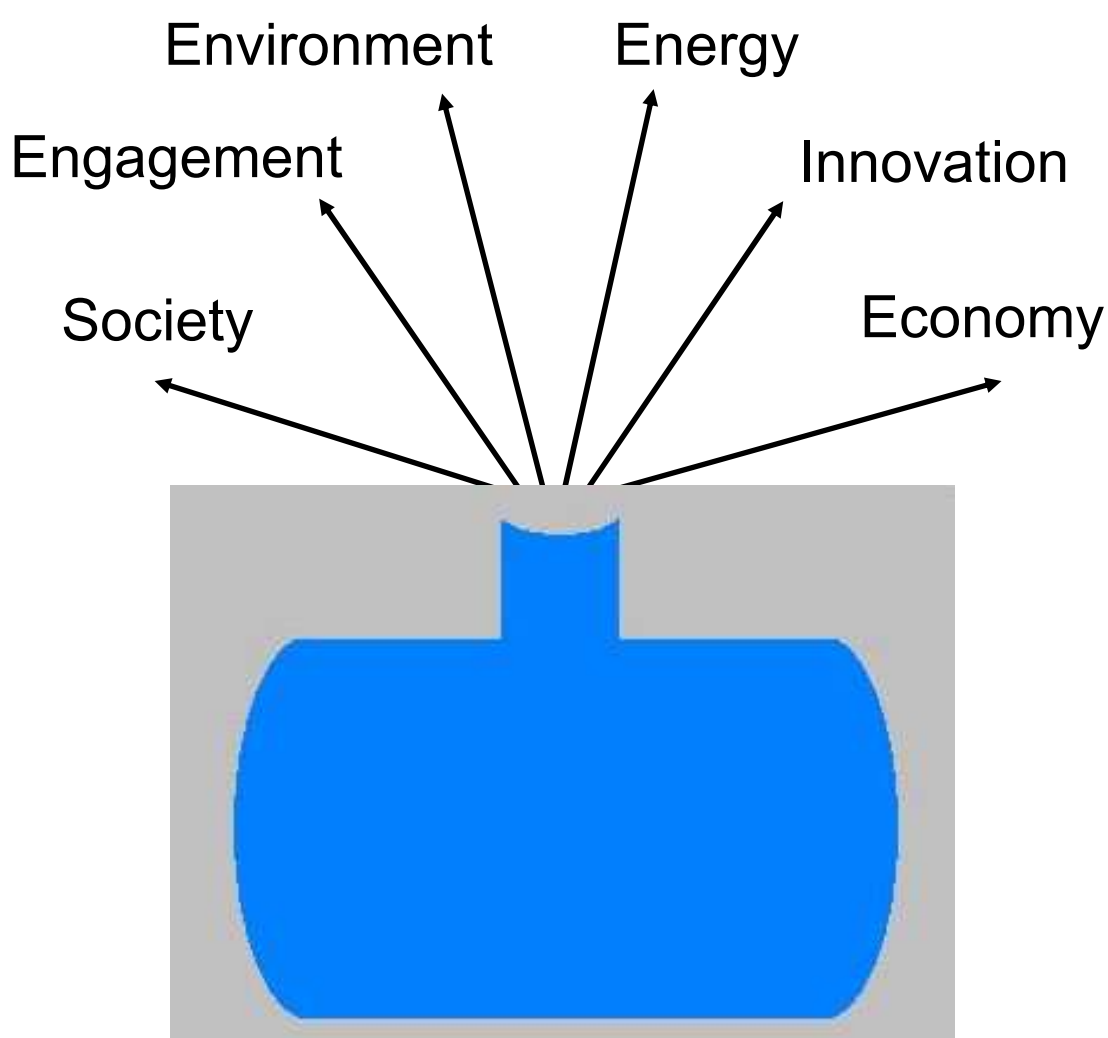




Rainwater Harvesting in the UK

Thinking Outside the Tank

A report on recent research



Oct 2011

EPSRC
Pioneering research
and skills

A report based on research undertaken for the Water
Cycle Management for New Developments (WaND)
Project (2003-2007)

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Forward.....

As a water retention technique, rainwater harvesting has been around for thousands of years - and it will be around for as long as humans are. However, in recent years as systems have become more technology-based, muddled messages around their use have clouded the way in which rainwater harvesting is viewed in the UK. This report summarises the results of recent research undertaken at the University of Exeter. I hope it will help dispel some of the myths and mean rainwater harvesting can come out of the clouds and into the mainstream, when considering alternative water systems as part of the integrated water management supply-demand 'toolbox'.

.....Dr. Sarah Ward, Principal Investigator, RWH in the UK
(RWHUK) Project

Contents

Background to the Research	5
Key Findings - A Summary	6
Society - Policy and People	7
Engagement - Beyond Information	8
Environment - Balancing Needs	10
Energy - A Benchmarking Method	11
Innovation - Technical Relevance	12
Economy - Future Markets	13
A Vision and Strategy for the Future	14
Implementing the Strategy	15
Abbreviations, Equation Definition of Terms and Key References	16
Contact List	17

Background to the Research

Undertaken between 2007 and 2010, the Rainwater Harvesting in the UK (RWHUK) project, aimed to fill some of the socio-technical knowledge gaps in relation to rainwater harvesting system implementation and utilisation in the specific context of the UK. Although the UK was the focus, case studies and findings across the international RWH arena were drawn into the research, ensuring that it represents a global 'state-of-the-art' investigation into the technology. The research was undertaken at the University of Exeter's Centre for Water Systems. It utilised a range of methods to collect, analyse and interpret data and evidence, from a number of local, national and international case studies, which resulted in the formulation of the vision and strategy presented on page 14. The primary local case study was the Innovation Centre at the University of Exeter, which has a RWH system, illustrated below. Pre and post-implementation socio-technical data were collected for the Innovation Centre, forming a comprehensive recent UK-based case study.

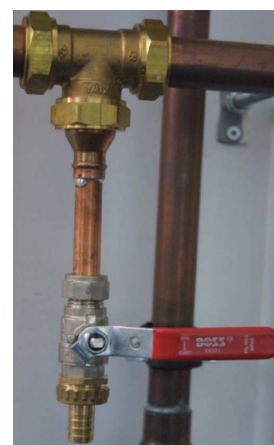
The Innovation Centre building in Exeter



The underground storage tank for the RWH system



Monitoring equipment for the RWH system - meters (left) and water quality sampling point (right)



Using this Report

This report gives an overview of the RWHUK project research. It is not intended to give full details about all aspects of or methodologies used within the research. It is designed to give summaries of the most pertinent findings, as well as providing signposts to other resources (journal articles, book chapters) for further information, as required by the reader.

Key Findings - A Summary

- There is a need for policy clarity in relation to RWH - current policy, regulation, standards and guidance convey conflicting messages (page 7 and 11)
- Contrary to popular belief, utilisation of RWH does not pose a significant health risk and people are receptive to the technology (page 8)
- There is a greater need for publicity about demonstration sites and exemplars in order to build confidence in systems with potential implementers (developers, SMEs) and water-users in general (page 8)
- A central, independent body should guide stakeholders on how the implementation process works and in the potential ways RWH may be relevant to them (page 8)
- A range of technical barriers limit the relevance of the current systems on the market - industry innovation could overcome these, increasing adoption of RWH (page 8, 11, 12 and 13)
- Quick resolution of operation and maintenance issues is crucial for resolving impediments to system performance (page 12)
- More flexible and readily retrofittable RWH system designs may be better suited to the UK, particularly in the future (page 12)
- For large buildings, pumped systems require minimal energy consumption compared to overall building energy consumption (page 11)
- New low-energy or pump-free systems can offset concerns about energy consumption (pages 10 to 12)
- Support mechanisms could include direct or indirect incentives, such as subsidies for feasibility assessments or increasing the applicability of tax-relief schemes to a wider audience (page 12)
- A vision and strategy have been developed to evolve the RWH sector in the UK, which will require stakeholders to form alliances to implement it in innovative and sustainable ways (pages 14 and 15)

Society - Policy and People

The UK is perhaps in a period of flux in relation to water management practices, with the implementation of the Flood and Water Management Act, a forthcoming Water White Paper and a new Draft Planning Policy Framework (which does not explicitly refer to sustainable or integrated water management). These pieces of legislation build on a lot of activity over the last few years, where a lot of policy documents have looked at different aspect of the water management cycle - some of which are illustrated in the table below (Ward *et al.*, 2011d).

	Year	Document	Org.
Regulatory	2007	Funding and Charging Arrangements for SUDS	DEFRA
	2007	Powers to Restrict Non-Essential Uses of Water	DEFRA
	2007	Water Metering in Areas of Serious Water Stress	DEFRA
	2008	Climate Change Act	DECC
	2008	Private Water Supplies (England) Regulations	DEFRA
	2009	Charging for Household Water and Sewerage Services	DEFRA
	2009	Revision to Building Regulations Part G (sanitation and water efficiency)	DCLG
	2009	Revision to Building Regulations Part H (drainage and waste disposal)	DCLG
	2010	Flood and Water Management Act	UK Gov
Policy	2006	Code for Sustainable Homes	DCLG
	2006	Planning Policy Statement 25: Development & flood risk	DCLG
	2007	Planning Policy Statement 1: Supplement: climate change and sustainable development	DCLG
	2008	Future Water – water strategy for England	DEFRA
	2008	Improving Surface Water Drainage	DEFRA
	2008	Draft PPS: Eco-towns	DCLG
	2009	Water for People and the Environment – water resources strategy for England and Wales	EA
Guidance	2006	Water Efficiency in New Buildings	DCLG, DEFRA
	2007	Conserving Water in Buildings	EA
	2009	Public Understanding of Water Use in the Home	DEFRA
	2010	BSI 8525-1:2010 Greywater systems Part 1: Code of practice	BSI
	Forthcoming	BSI 'Strategy for Water Reuse'	BSI

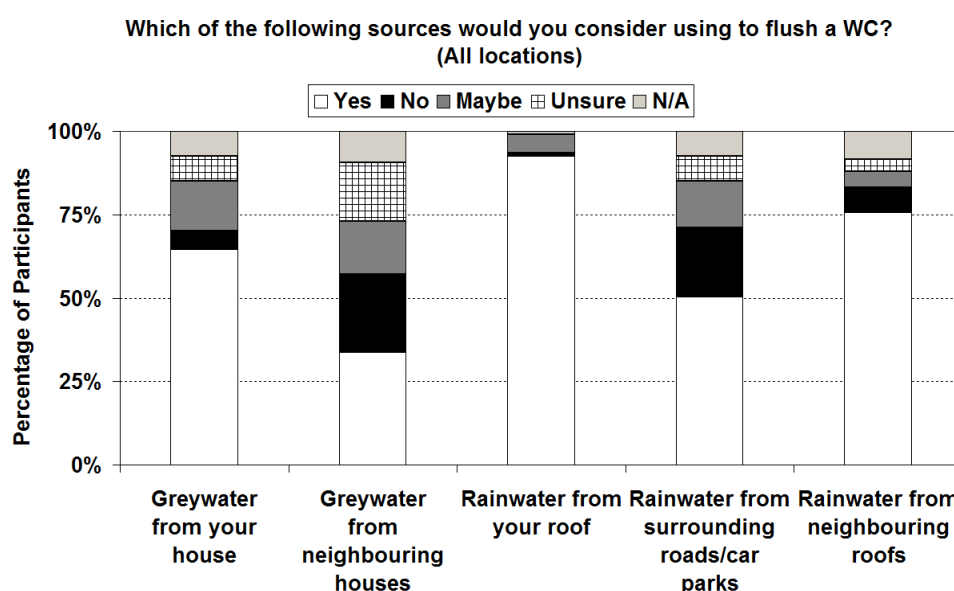
Water-related organisations have also undergone reviews, with changes in process and practise happening in some (EA) and expected across others (Ofwat). Changes in the way Ofwat operates may encourage Water Companies to search for new and innovative ways of co-producing water supply and drainage benefits, beyond the traditionally accepted capital intensive projects, which RWH can assist with (Kellagher, 2011). Policy changes in relation to sustainable drainage systems (SuDs) also mean that some housing developers are beginning to look for other water-supply-side techniques, in order to meet Code for Sustainable Homes criteria. However, tools recommended within such guidance documents are not always the most suitable and developers are not being encouraged to use the most appropriate ones when designing systems. Other policies and guidance documents have also given rise to a new consideration of alternative water systems - as the realisation beckons that water efficiency schemes can only do so much to reduce *potable* water demand. Of particular relevance to RWH is the forthcoming British Standard Institute's 'Strategy for water reuse' (BS 8585), which builds on the previous two for RWH (BS 8515) and greywater (BS 8525). BS 8585 will give coarse guidance on which types of reuse may be suitable for different contexts and scales. The University of Exeter is part of the consortium working on the development of the standard.

However, in all this talk on policy, it must not be forgotten that the key to successful implementation of reuse/RWH projects, is their acceptance by the general public, who are all 'water-users' and represent a vast number of stakeholder groups. Before appropriate implementation can really be viewed as part of the water management 'toolbox', the technology must first be mainstreamed into the public psyche.

Engagement - Beyond Information

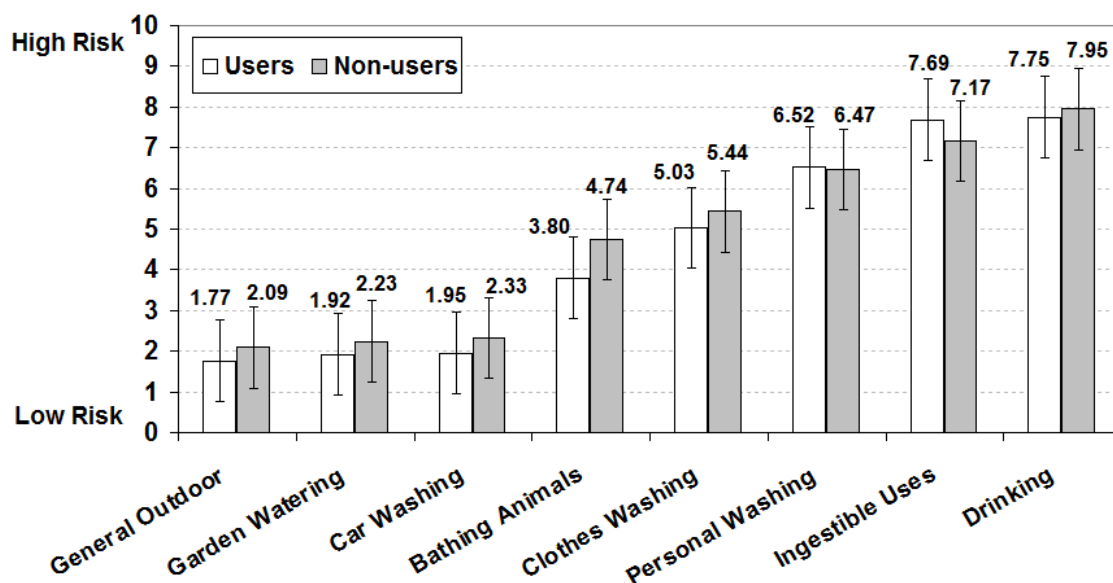
Mainstreaming RWH as a concept is not that difficult to achieve - a large number of people have water butts in their gardens. What is difficult to achieve is the mainstreaming of the concept of implementing a system to supply rainwater *into buildings*. Reliance on the centralised water distribution system is engrained in everyday water-using practices. Consequently, introducing a new technology, producing a different, non-drinking quality of water is one of the highest hurdles to overcome (Ward, 2010; Ward *et al.*, 2011). Over the last few years the number of systems installed in communal buildings (schools, offices, visitor centres) has increased - but often it is not known by the building's occupants that a system is in use - which does nothing to raise the national profile of RWH. A national portfolio of 'demonstration sites' or a 'buddy' database could facilitate visibility of existing 'best practise' installations - which would help increase receptivity.

Concerns over health impacts also often cloud decisions to implement RWH. A water quality and health impact assessment (HIA) of the Innovation Centre RWH system (see page 5) identified that the health risk associated with using rainwater to flush a toilet was minimal, even in a building with design features that potentially compromised the harvested rainwater quality (Ward, 2010; Ward *et al.*, 2010b). The HIA determined the risk posed to be comparable to that of being struck by lightning (using the 'disability affected life years' (DALY) measure). Despite the concerns outlined (which are often touted at the policy, rather than operational, level), the RWHUK research showed that people are open to the idea of RWH (see chart below) and would even consider household or business-scale implementation.



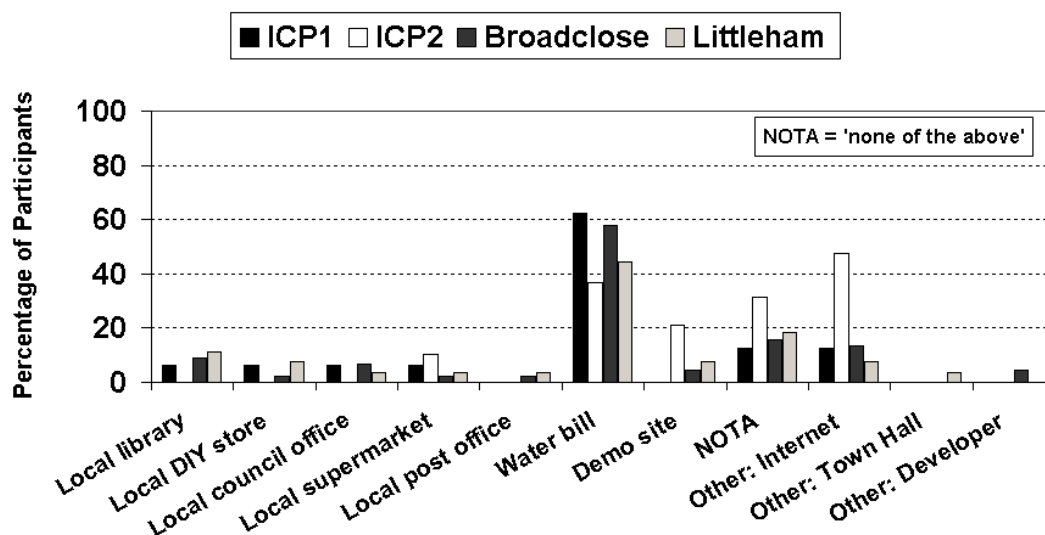
They also associated a low risk with most of the uses for which RWH is currently acceptable in addition to toilet flushing, such as laundry use (see chart over the page). However, they were not keen on the associated capital and maintenance costs, in both time and money. At present only businesses are eligible for tax-relief incentives on RWH equipment via the Enhanced Capital Allowance scheme using the Water Technology List. Interviews with small to medium enterprises (SMEs) re-

Survey participants responses to a question asking about their perceived risk associated with different end uses for harvested rainwater.



vealed that these are difficult to administer and provide limited actual benefit. Additionally, they revealed that access to independent information about RWH is very tricky to find - most of the information available is produced by manufacturers and not seen as trustworthy. Furthermore, a survey conducted with householders at four different locations identified that although they would like to see RWH information included with their water bills (see chart below) , the cost and maintenance aspects of the systems currently available were prohibitive. This suggests that increasing the efficacy of current systems for different future markets and providing incentive mechanisms are vital for RWH to grow as a sector. This illustrates that information provision should not be the primary focus of a strategy to grow the UK RWH sector.

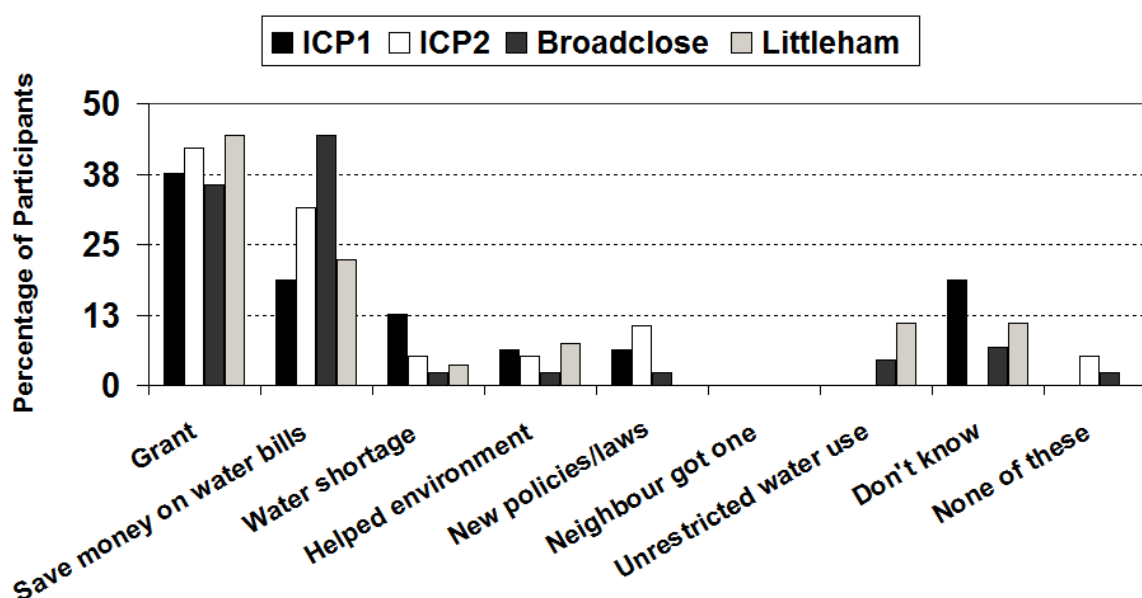
Where would be the best place for you to access information on rainwater harvesting systems?



Environment - Balancing Needs

Participants in the survey and interview parts of the research also showed that they were aware of the potential environmental benefits of RWH. When asked about factors that would encourage them to implement RWH, over 70% agreed it was a good thing to save highly-treated drinking water and use rainwater for non-potable uses, for environmental reasons (to keep water in the environment). However, issues of cost and maintenance were more pertinent for their consideration of implementing a system (see chart below). This indicates that although the environmental contributions RWH can make are recognised, other factors take precedence, revealing that balancing the water needs of people/society and the needs of the environment has to come at a price (Ward, 2010).

Factors encouraging consideration of RWH system implementation



Another environmental benefit of RWH, is the reduction in (or slowing in the release of) surface water runoff to combined sewers (Hurley *et al.*, 2008). This reduction means that the chances of a combined sewer overflow (CSO) discharging (releasing effluent into the environment) could be reduced. The resultant impact would be reduced releases of contaminated water into the environment and therefore reduced negative impacts, such as degraded water quality and the associated impacts on aquatic flora and fauna (e.g. fish kills or eutrophic algal blooms).

A further, currently controversial, area of environmental impact surrounding RWH systems, is their use of energy - both operationally (for pumping) and embodied in their production. Utilising RWH systems in some areas of the UK (those under particular water stress), may require a trade-off between water saving and energy saving. Balancing which may be environmentally detrimental or beneficial on the whole (globally) or for a particular location is a difficult challenge. The issue of energy is discussed in detail on the next page.

Energy - A Benchmarking Method

An Environment Agency report (Parkes *et al.*, 2010) released whilst the RWHUK project was being undertaken, criticises traditional RWH systems for their embodied and operational energy requirements. However, the report comes with caveats - that it does not consider gravity systems and that the method is not a full life cycle assessment (it uses the Average Incremental Carbon and Social Costs). It therefore does not take into account trade-offs between water saving and energy saving or provide a full comparison in relation to existing water distribution infrastructure. It also does not consider RWH systems whose components are manufactured from recycled materials (such as recycled plastics for storage tanks). The report concludes that utilisation of a RWH system (within the scope of the report) increases embodied and operational carbon emissions, based on the additional energy consumption required in their production and operation over that of existing water distribution infrastructure. Operational energy was identified as a particular culprit, due to the presence of a pump in most traditional system configurations.

The timing of the EA report meant that a full life cycle assessment of different RWH systems could not be undertaken by the RWHUK project. However, a new method was developed for estimating the operational energy consumption associated with pumping and UV disinfection in RWH systems. The method provides a detailed procedure to allow comparison of operational energy consumption across different pumped RWH systems, highlighting where energy and carbon contributions may exceed water saving benefits. The full method and algorithms are described in detail in Ward *et al.* (2011b) and Ward *et al.* (2012), but an overview and case study are provided here. Analysis of previous methods and pump specification documents led to the derivation of the following equation, which estimates total pump and UV operational energy consumption (please refer to page 16 for term definitions):

$$E_{TOTO} = E_2 + (E_2(1 - P_E)) + E_{UV}$$

This uses a range of parameters, including pump capacity, rating and efficiency, the header tank switch-on/off levels and the volume of rainwater pumped, to calculate the pump start up and operating durations of the pump, eventually leading to the calculation of total pump operational energy consumption. The UV element is calculated from the UV unit rating and operational duration. The equation can then be used with carbon dioxide conversion factors to estimate carbon emissions, using the following equation:

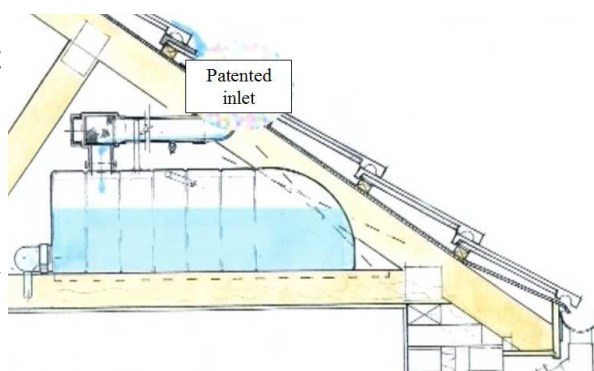
$$E_{CO_2} = E_{TOTO} \cdot E_C$$

Applying the method to empirical data from the Innovation Centre case study system, described on page 5, showed that energy consumption associated with pumping 1m³ of rainwater was 0.54 kWh. The overall contribution from pumping was minimal and for a period of 6 months represented just 0.07% of the building's total energy consumption. By way of comparison, the EA report identified the water distribution system energy consumption (for water delivery only) as being 0.6 kWh/m³. This comparison illustrates that, for large buildings, RWH system energy consumption should not be a deterrent to implementation. However, for other building scales, such as households, more comparative research applying the method is required and for this scale more innovative gravity systems may be more appropriate.

Innovation - Technical Relevance

As highlighted in a number of sections in this report, technical innovation of RWH systems is key, particularly for application at the household scale in the UK. Even with the Innovation Centre system, installation and operational challenges were encountered, due to the complexity of the process/configuration. Quick resolution of issues was key to resolving performance impediments (though the system yielded a high average water saving efficiency (Ward *et al.*, 2010; Ward *et al.*, 2011c)). At present system designs based on traditional systems from Germany and Australia are being implemented. However, these may not be most suitable for the UK context (UK houses generally do not have basements, as in Germany or large plot sizes, as in Australia) and are not the easiest to retrofit. Innovations in pump efficiency and interfacing RWH systems with renewable energy technologies, such as photovoltaic cells, have emerged over the last few years. Moving forward, the area of greatest potential is in gravity-based systems, as these eliminate the need for pumping and therefore concerns over operational energy consumption. A number of gravity systems are being developed around the world, some of which are illustrated here.

This patented system, under development at the University of Exeter, utilises several innovative technical developments, such as a tile-level runoff take-off point and eave-space storage. The system is highly retrofittable.



This gutter-based system is under development in Australia (Hardie, 2010). Space in specially-formed gutters is utilised for rainwater storage. The system combines storage with overflow-infiltration and is beneficial when plot size or internal roof space restricts the use of other storage tank types. However, it is potentially difficult to retrofit.

This system is from Korea and utilises a 'plastic bag' storage tank, (can be made from recycled plastic) which is ideal for situations where space constraints in dense high-rise buildings prevent installation of more conventional tanks (Dao *et al.*, 2009).



These experimental systems highlight that the future form of RWH systems will be very different to those currently being implemented in the UK. Not only are they less resource and capital intensive, they also require less maintenance - something rainwater-users of the future may find attractive (based on the findings presented on page 8).

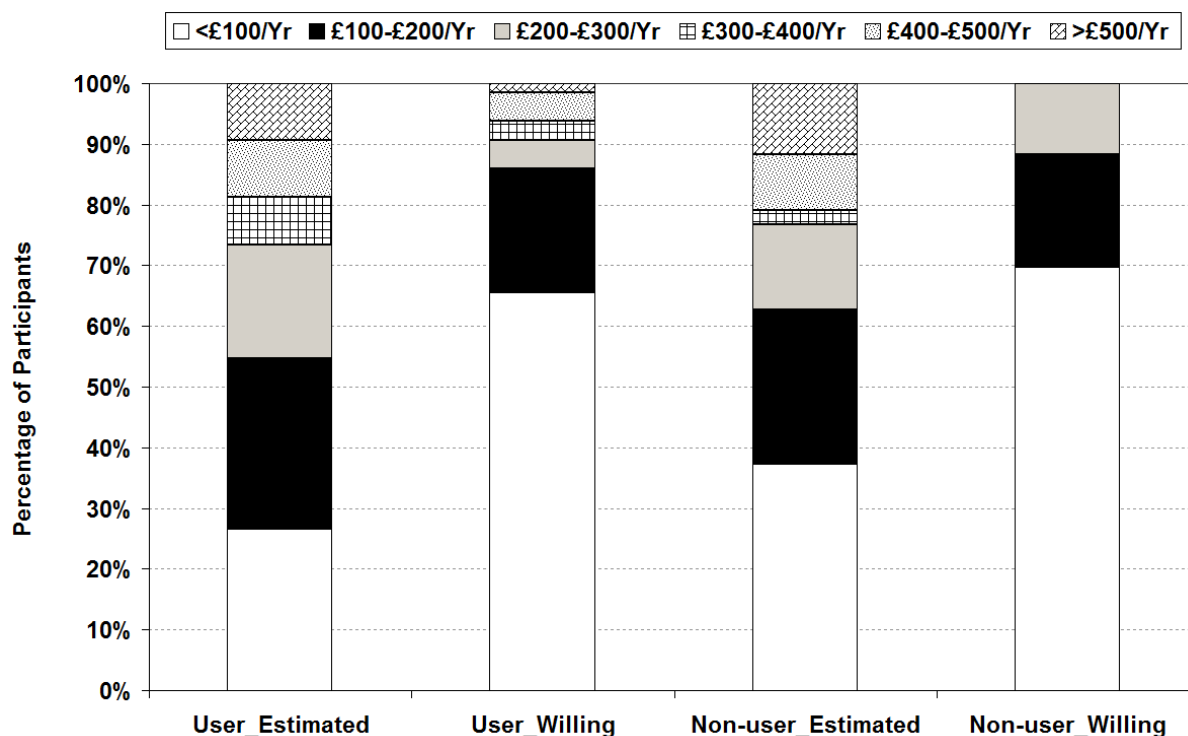
Economy - Future Markets

The experimental systems illustrated on the previous page demonstrate that future RWH systems will look very different to those we are familiar with today. This means that there will be new markets opening up, nationally and internationally. If the UK wants to be seen as both innovative and ahead of the game in both product development and the implementation of 'new' RWH systems, action needs to be taken now.

Development in the RWH sector represents an excellent example of how the current emphasis on economic growth can be coupled with an environmentally sustainable technology. However, many different aspects of the sector require significant attention, support and investment, if the UK is to feature in and exploit these future markets.

This is where links with policy, organisations and people need to be made. From the findings presented on page 8 and the chart below, it is clear that if household-scale systems are to be implemented, particularly retrofitted, then substantial product development is required and some sort of financial incentive will be key. This requires recognition at the policy level that current incentive schemes (of which there is only one and it only applies to businesses - see page 8) are not far-reaching enough and require adapting to generate future markets - similar to those created for renewable energy.

The framework on the following page outlines a strategy for the sustainable development of the RWH sector i.e. benefits for society, environment and the economy.

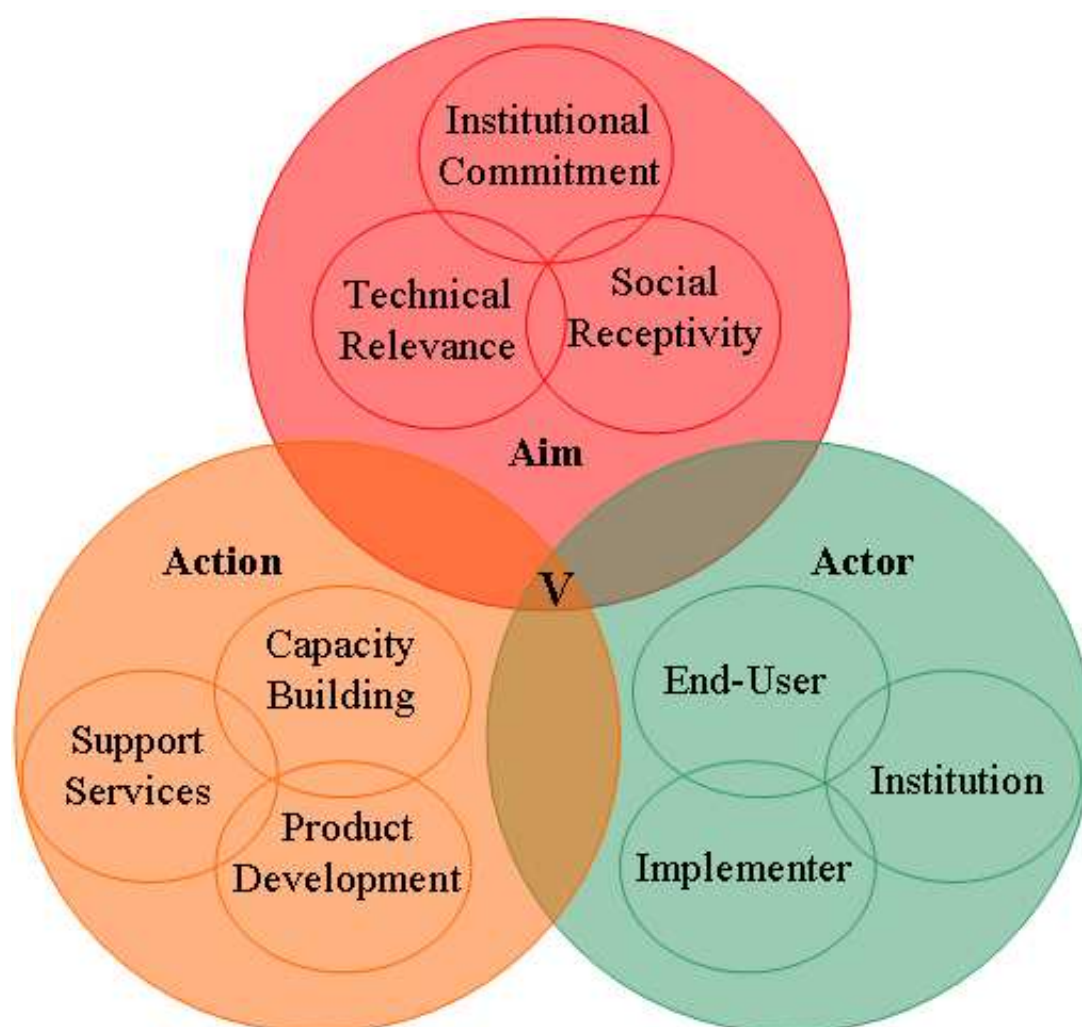


Survey participants' (RWH system users and non-users) responses regarding their perceived RWH system maintenance costs ('estimated') versus the amount they would be willing to pay ('willing').

A Vision and Strategy for the Future

In order to evolve into something suitable for an uncertain future, where adaptation and resilience are key features of a sustainable water system, the RWH sector requires actions in a number of areas. Triangulation of all of the research findings presented in this report, led to the development of a 'vision' for RWH and a strategy moving forward (Ward, 2010; Ward *et al.*, 2011). These are summarised in the diagram below and the implementation of the strategy is described on the next page.

The research identified that weak areas in the sector, at present, are technical relevance, social receptivity and institutional commitment. Correspondingly, what is needed are new products, greater capacity and more support. Therefore stakeholders from both top-down and bottom-up ends of the RWH sector need to meet in the middle, to implement change and work towards the RWH 'vision': an increase in the appropriate and successful implementation of RWH systems at a range of scales.



The strategy for developing the RWH system sector in the UK - integration of 'aims', 'actions' and 'actors' is vital for achieving the overall 'vision' (V) - an increase in the appropriate and successful implementation of RWH systems at a range of scales.

Implementing the Strategy

Different stakeholders have different parts to play in the development of the RWH sector in the UK - the table below illustrates just a few, to give the reader an idea of potential aims, actions and actors. Alliances between these actors are key (Potter *et al.*, 2011) and it is hoped that this document has provided enough research and direction to enable organisations and stakeholder groups to take some of these actions forward.

1. Policy Informer	Research Councils (e.g. EPSRC)	Undertaking cutting edge research through Universities and Institutions	Undertake fund research into <i>product development</i> to increase <i>technical relevance</i> of RWH systems to <i>end-users</i> and increase institutional confidence
	Consumer Council for Water (CCW)	The voice of UK water consumers	Inform consumers (<i>end users</i>) of potential alternatives to the centralised WDS to <i>build capacity</i> and increase <i>social receptivity</i>
	UK Water Industry Research (UKWIR)	Research for UK water operators	Investigate the impact of RWH on WDS/sewers to <i>enhance technical relevance/institutional commitment</i>
	Drinking Water Inspectorate	Independent research on water supply safety	Undertake and disseminate information regarding RWH health risks to all <i>actors</i> to address <i>social receptivity</i>
2. Policy Maker	EA	Water resources management/ environmental protection	Provide/signpost a central source of guidance/support to <i>build capacity</i> and <i>social receptivity</i> with <i>implementers</i> and <i>end-users</i>
	DEFRA	Environment/Water related policy	Use FPEB/segmentation to identify a greater range of <i>support services</i> for <i>implementers</i> and <i>end-users</i> to support all <i>actions</i>
	DCLG	Planning policy	Better signpost <i>support services</i> in PPSs
	DECC	Climate change adaption policy	Extend remit to cover the water-energy nexus to increase <i>institutional commitment</i>
	OFWAT	Water pricing policy	Incentivise WSPs to consider alternatives to increase <i>institutional commitment</i>
3. Policy Implementer	Local Authorities	Building control and the planning system	Signpost the EA/Greenplumb <i>support services</i> through the existing www.direct.gov.uk 'find a plumber' facility to enable <i>implementers</i>
	Water service providers	Planning and investing in infrastructure	Extend water efficiency information to cover RWH to increase <i>end user social receptivity</i>
	Water Managers	Consultancies undertaking SWMPs, FRMPs etc	Increase consideration of SWM options to <i>enhance social receptivity/capacity building</i>
	Architects	Designing new buildings and developments	Increase awareness of tools/data for designing RWH systems to <i>enhance technical relevance</i>
	Developers	Constructing new buildings and developments	Campaign for greater <i>product development</i> and <i>support services</i> to increase <i>technical relevance</i> and <i>build capacity</i> for <i>implementers</i>
	RWH System Suppliers	Product designers/manufacturers	Undertake <i>product development</i> activities to increase <i>technical relevance</i> to <i>end-users</i>

List of Abbreviations

BSi - British Standards Institution
DECC - Department for Energy and Climate Change
DCLG - Department for Communities and Local Government
Defra - Department for Environment, Food and Rural Affairs
EA - Environment Agency
EPSRC - Engineering and Physical Sciences Research Council
Ofwat - economic regulator for the water and sewerage industry in England and Wales
SuDS - Sustainable Drainage Systems

Equation Definition of Terms (Page 11)

E_{TOTO} = total operational energy consumption (UV and pumping), kWh
 E_2 = total energy consumed during pump start-up and operation phases, kWh
 P_E = pump efficiency, %
 E_{UV} = energy consumed by UV device, kWh
 E_C = carbon dioxide emitted from the energy production source, kg
 E_{CO_2} = carbon dioxide emission associated with the operational energy consumption, kg/kWh

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Related presentations from two workshops held in 2011 can be downloaded from:

http://centres.exeter.ac.uk/cws/downloads/cat_view/68-rainwater-harvesting-events

Additional copies of this report can also be downloaded from this location

For more information about the WaND Project, please visit:

www.wand.uk.net

Or purchase a copy of the final report:

Butler, D., Memon, F. A. Makropoulos, C., Southall, A. and Clarke, L.
(2010) Guidance on water cycle management for new developments
(WaND), C690, ISBN: 978-0-86017-690-9.

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